



Effect of Integrated Nutrient Management Practices on Physiology and Yield of Improved Traditional Rice Variety (Black Kavuni)

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ABSTRACT

Background: Increased demand for quality based rice and rice products motivate the farmers for producing the traditional rice varieties. To meet the demand, rice production need to be substantially increased with suitable nutrient management practices.

Methods: The field experiment was conducted during *Early kar* (2023) and *Late samba* (2023-24) seasons at Wetland farm, Department of Agronomy, TNAU, Coimbatore. The experimental design consisted of twelve treatments laid out in Randomized Block Design with three replications. Based on N equivalent basis, required quantity of inorganic fertilizer, farmyard manure, vermicompost and poultry manure were applied to rice.

Result: The results revealed that application of 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + Foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tilling, PI and Flowering stage (T₁₁) registered higher physiology, yield parameters and grain yield.

Key words: Chlorophyll content, Improved kavuni, Yield parameters, Yield.

INTRODUCTION

Rice (*Oryza sativa* L.) crop occupies prime place among food crops cultivated around world. It remains as most important staple food crop of world (Krishnan *et al.*, 2011). It provides major source of calories for 40 per cent of world's population (Virdia and Mehta, 2009). India is the largest producer of rice in the world after China. In India rice occupied an area of 46.3 m.ha with a production of 129.5 mt and productivity of 2798 kg ha⁻¹ (Indiastat, 2021-2022). Nowadays, there is an increased demand for quality based rice and rice products, which could lead the farmers in producing the traditional rice varieties that are producing stable yields even under unfavorable environmental and soil conditions. Black kavuni has strong antioxidant activity, which modulates various health benefits like anti-inflammatory, anti-cancer, immune modulatory and anti-allergic properties, it has been referred to as a super food (Sakshi Bhardwaj *et al.*, 2023). The black kavuni is season bound rice variety. According to Radha *et al.* (2022) suitable season for growing this variety is September to January and it is photosensitive in nature. Whereas, the improved kavuni rice variety CO 57 is suitable for all seasons, photo insensitive in nature and produces 55.74% higher yield than traditional black kavuni. This variety was released during 2023 from Tamil Nadu Agricultural University. It has high nutritional value due to the high fibre protein but less of carbohydrates. Since, its glycemic index is lesser, it prevents sudden increase in blood sugar levels. It also has an anticancer effect due to presence of flavonoids (TNAU Agritech Portal, 2023).

Sustainable agricultural production requires the development of an effective fertilization strategy that

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increases agricultural productivity and environmental quality while utilizing both chemical and organic manures (Kalita and Deka, 2006). In view of maintain in soil fertility and sustainable agricultural production, adoption of integrated nutrient management practices is one of the feasible option. Combining inorganic and organic manures effectively improves soil health and increases nutrient use efficiency in addition to maintaining crop productivity (Verma *et al.*, 2005). Sonamati Neti *et al.* (2022) stated that the application of organic manures along with chemical fertilizers may reduce nitrogen loss and improve its availability during the crop's growing season. Therefore, the present investigation was planned with the objective of

evaluating the effect of integrated nutrient management practices on growth, yield attributes and yield of improved traditional rice variety, black kavuni.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out during *Early kar* (April - August, 2023) and *Late samba* (September-January, 2023-24) at Wetland Farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. It was located at 11°01'06"N Latitude, 76°58'21"E Longitude and 426.7 m above MSL. The soil of the experimental field was clay loam in texture with pH range of 8.12 and 8.0, EC was 0.47 and 0.45 dsm⁻¹. The soil nutrient status was low in available nitrogen (215 and 226 kg ha⁻¹, respectively), medium in available phosphorus (20.8 and 21.9 kg ha⁻¹, respectively) and high in available potassium (692 and 699 kg ha⁻¹, respectively).

Experimental design and treatments

The experimental design consisted of twelve treatments laid out in Randomized Block Design (RBD) with three replications. The treatments comprised of T₁ - Control (Without fertilizer), T₂ - 100% RDN through inorganic fertilizer, T₃ - 50% RDN through inorganic fertilizer + 50% RDN through FYM, T₄ - 50% RDN through inorganic fertilizer + 50% RDN through poultry manure, T₅ - 50% RDN through inorganic fertilizer + 50% RDN through vermicompost, T₆ - 50% RDN through inorganic fertilizer + 25% RDN through poultry manure + 25% RDN through vermicompost, T₇ - T₄ + Foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering and PI stage, T₈ - T₅ + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering and PI stage, T₉ - T₆ + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering and PI stage, T₁₀ - T₄ + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering, PI and Flowering stage, T₁₁ - T₅ + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering, PI and flowering stage and T₁₂ - T₆ + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering, PI and Flowering stage.

Crop management

The rice variety CO 57 (Improved black kavuni, duration-130 to 135 days, average yield 4.6 t ha⁻¹, medium grain black rice) was used in this experiment. Paddy seeds are directly sown in nursery bed with a thin film of water. After 30 days the rice seedlings were transplanted to main field with puddled soil condition. The spacing adopted was 25 × 25 cm during *Early kar* (April - Aug, 2023) and *Late samba* (Sep - Jan, 2023-24) seasons. The recommended dose of N (150 kg ha⁻¹) was applied as per the treatment schedule. N and K were applied at basal, tillering, panicle initiation and heading stages. P was given at full dose as a basal application. The organic manures are applied at basal as per the treatment schedule. Before the application the N content was analysed in different organic manures.

The nitrogen content of FYM, poultry manure and vermicompost were 0.43, 2.92 and 2.26 per cent, respectively.

Analysis of photosynthetic pigments

Total chlorophyll was analysed by DMSO (Dimethyl Sulphoxide) method (Hiscox and Israelstam, 1979). Total chlorophyll content values are calculated by using the following formula (Yoshida, 1972).

Total chlorophyll =

$$(8.02 \times \text{OD at } 663) + (20.2 \times \text{OD at } 645) \times \frac{V}{1000 \times W}$$

Where,

OD - Optical density,

V - Final volume of supernatant.

W - Weight of the leaf sample taken in gram.

Assessment of gas exchange parameters

The leaf gas exchange parameters were measured by using portable photosynthesis system (Model LI-6400 of LICOR inc., Lincoln, Nebraska, USA). The leaf gas exchange parameters such as photosynthetic rate (Pn: $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), stomatal conductance (Gs: $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$) and transpiration rate (E: $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$) were recorded.

Assessment of normalized difference vegetation index (NDVI)

Green Seeker was used to measure the Normalized Difference Vegetation Index (NDVI). It is a remote sensing technique that assesses the quantity and quality of vegetation in a given area.

Yield attributes and grain yield

The number of productive tillers from each plot were counted and expressed in numbers m⁻². Total number of filled grains was counted from panicles. In order to calculate the 1000-grain weight (g), the number of grains from each treatment was counted and the weight was then determined. After harvesting of the crop grain yield was calculated.

Statistical analysis

Data collected on various parameters were analysed for randomized block design by using R software version 4.2.0 (R Studio 2022.02.3+492) to find the significance difference at 5% level, which was used to test for significant differences among 12 treatment means.

RESULTS AND DISCUSSION

Total chlorophyll

Higher total chlorophyll content were recorded with the application of 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering, PI and Flowering stage (T₁₁) (2.14 and 2.18 mg g⁻¹ during *Early kar* and *Late samba* seasons, respectively) and it was on par with 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering and PI

stage (T_8) (Fig 1). The highest amount of leaf chlorophyll content was observed when Fe and Zn were applied together. This could be due to activity of Zn for the synthesis of chlorophyll and the formation of carbohydrates, while Fe is important for the formation and development of chlorophyll. These results fall in line with the findings of Kobraee *et al.* (2011). Foliar sprayed Zn and Fe, which are essential for chlorophyll synthesis and involved in pyrrole ring formation, a structural component of chlorophyll (Rakesh *et al.*, 2012). Chlorophyll a is the main pigment involved in photosynthesis; chlorophyll b receives light energy and transfers it to chlorophyll a. As vital structural elements of the photosynthetic antenna, they take part in the process of absorbing light energy for photosynthesis (Zakar *et al.*, 2016). According to Shah *et al.* (2017), precisely estimating the photosynthetic pigments in leaves is crucial to regulate fertilizer application and maintaining the general health of the crop. Integrated application of organic and inorganic nutrients by providing immediate and prolonged nitrogen availability to rice crops. This results in increased leaf expansion, leading to better solar radiation interception of the leaf, which enhances the chlorophyll content. These results are in conformity with the findings of Samant *et al.* (2022). Lower total chlorophyll content were observed in control (T_1).

Gas exchange parameters

During *Early kar* and *Late samba* seasons, the highest photosynthetic rate (Pn: 29.6 and 29.9 $\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), stomatal conductance (Gs: 0.28 and 0.36 $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$) and transpiration rate (E: 5.84 and 7.09 $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$) were recorded with the application of 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5 % ZnSO_4 + 1% FeSO_4 at tillering, PI and

flowering stage (T_{11}) (Table 1) and it was comparable with T_8 . One of the main mechanisms underlying plant growth is photosynthesis and photosynthetic metabolism is carefully controlled to maximize growth under various N sources (Bruck and Guo, 2006). According to Tadashi Hirasawa *et al.* (2010) application of nitrogen may lead to increased hydraulic conductivity, which in turn may lead to increased stomatal conductance in the leaves. Increases in photosynthetic rate, stomatal conductance, transpiration rate and intercellular CO_2 concentration with increase in leaf nitrogen content. The positive improvements in gaseous exchanges in rice could be attributed to increased nutrition supply by applying organic and inorganic nutrients, which improves metabolism. These results fall in line with the findings of Adriano Nascente *et al.* (2019). The lowest gas exchange parameters was observed in control (T_1) in both seasons.

Normalized difference vegetation index (NDVI)

Application of 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5% ZnSO_4 + 1% FeSO_4 at Tillering, PI and Flowering stage (T_{11}) (0.83 and 0.88, during *Early kar* and *Late samba* seasons, respectively) registered higher vegetation index and it was comparable with T_8 (Fig 2). This may be the result of higher chlorophyll content in the plants, improved canopy coverage and biomass production by timely application of both organic and inorganic nitrogen. These results fall in line with the findings of Dhital (2011). Application of inorganic N fertilizer along with organic nutrient sources will increase mineralization and immobilization of organic N and reduce nitrogen losses. The increased nitrogen content associated with proroplasm synthesis in plants led to vigorous vegetation. The higher vegetative index results increased

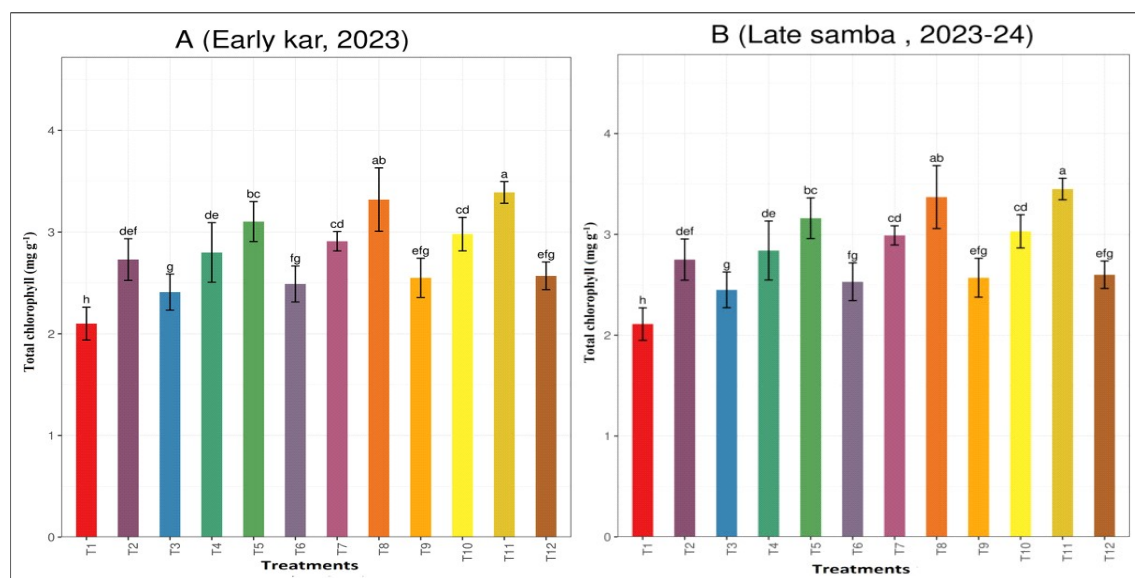


Fig 1: Effect of INM on (A.) Total chlorophyll content (mg g^{-1}) during *Early kar* (2023) (B.) Total chlorophyll content (mg g^{-1}) during *Late samba* (2023-24) of rice.

growth and number of tillers which ultimately enhanced rice yield. This corroborates with findings of Rasool *et al.* (2013) and Shenoy and Siddaraju (2020). According to Oforo Didas Kimaro *et al.* (2022) high levels of chlorophyll content are indicated by high NDVI values. The most crucial component of the rice plant for photosynthetic activity is chlorophyll, which forms carbohydrates to make rice plant tissue and rice grain. This process has a major impact on crop productivity. Control (T_1) registered the lowest vegetation index at flowering stage.

Yield attributes and yield

The yield attributes (Table 2) and yield (Fig 3) were significantly influenced by different nutrient management practices. During *Early kar* and *Late samba* seasons, application of 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5 % $ZnSO_4$ + 1% $FeSO_4$ at tillering, PI and flowering stage (T_{11}) registered higher yield parameters viz., number of productive tillers m^{-2} (309 and 335), number of filled grains panicle $^{-1}$ (176 and 185), 1000-grain weight (22.00 and 22.09 g ha^{-1}) and grain

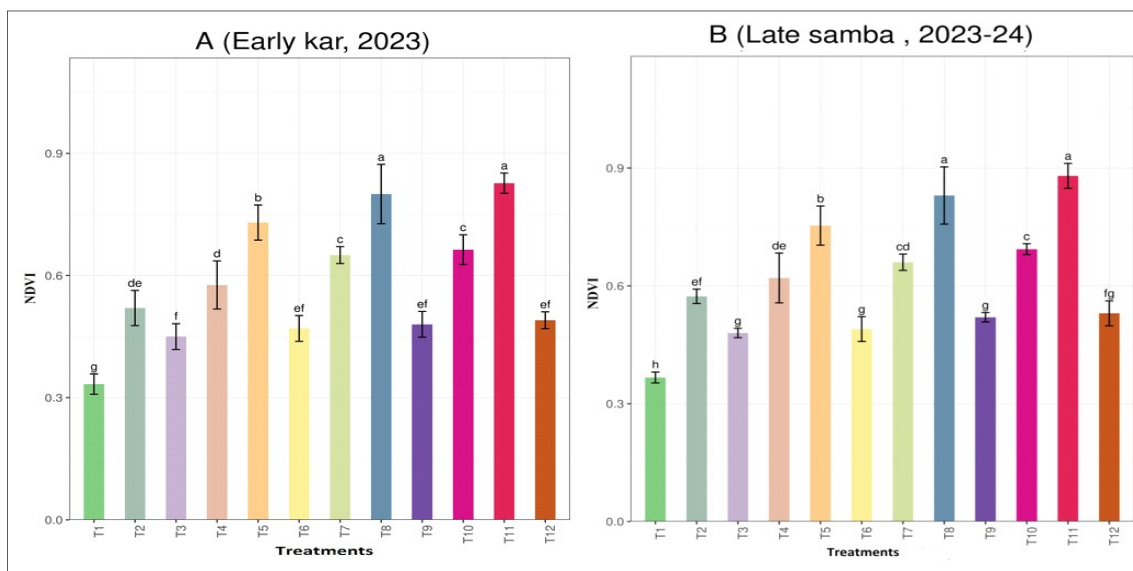


Fig 2: Effect of INM on (A) NDVI during *Early kar* (2023) (B) NDVI during *Late samba* (2023-24) of rice.

Table 1: Effect of INM on gas exchange parameters of rice.

Treatments	Gas exchange parameters*					
	Early kar (2023)			Late samba (2023-24)		
	A	gs	E	A	gs	E
T_1	18.0h	0.15g	2.69f	18.1i	0.15g	2.84f
T_2	24.3def	0.21de	4.85cde	24.7efg	0.23de	5.03de
T_3	20.1g	0.18f	4.52e	20.8h	0.18f	4.70e
T_4	25.0cde	0.22cd	4.92bcde	25.4def	0.25d	5.41d
T_5	27.2b	0.25b	5.33b	27.6bc	0.32b	6.50b
T_6	22.5f	0.19f	4.57e	22.8gh	0.19f	4.79e
T_7	26.0bcd	0.22cd	5.09bcd	26.8cde	0.28c	5.97c
T_8	29.5a	0.27ab	5.81a	29.7ab	0.35a	7.05a
T_9	23.0f	0.20ef	4.63e	23.9fg	0.21e	4.85e
T_{10}	26.4bc	0.23c	5.14bc	26.9cd	0.29c	6.00c
T_{11}	29.6a	0.28a	5.84a	29.9a	0.36a	7.09a
T_{12}	23.2ef	0.20ef	4.67de	24.1fg	0.22e	4.88e
SEd	0.91	0.01	0.21	1.01	0.01	0.24
CD (P=0.05)	1.89	0.02	0.43	2.10	0.02	0.49

*A- Photosynthetic rate ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$).

gs- Stomatal conductance ($\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$).

E- Transpiration rate ($\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$).

yield (3972 and 4114 kg ha⁻¹, during *Early kar* and *Late samba* seasons, respectively). However, it was comparable with 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering and PI stage (T₈). This might be attributed due to application of organic along with inorganic sources of nutrients may have provided the essential nutrients and served as a catalyst for the effective utilization of applied nutrients to increase the grain yield. Additionally, the basal dose of vermicompost application might have resulted in gradual release of nutrients might have synchronised with crop growth need (Choudhary and Suri, 2014). The rice plants are able to assimilate sufficient photosynthetic products due to the slow release and continuous supply of

nutrients in balanced quantities throughout all growth stages by the application of organic sources of nutrients. This might be due to increased dry matter and source capacity, which could lead to the production of more panicles with more fertile grains and higher test weight and grain yield (Singh *et al.*, 2015). According to Baishya *et al.* (2019) Zn and Fe are necessary for several enzymes that regulate plant metabolism. They are involved in the synthesis of auxin, the conversion of carbohydrates and the control of sugar in plants. Application of Zn and Fe, which are involved in the production of growth-promoting hormones and the reproduction process of many plants, is essential for grain formation. Effective tiller production is determined by a balanced supply of nutrients and the ability

Table 2: Effect of INM on yield parameters of rice.

Treatments	<i>Early kar</i> (2023)			<i>Late samba</i> (2023-24)		
	No. of productive tillers m ⁻²	No. of filled grains panicle ⁻¹	1000 grain weight (g.)	No. of productive tillers m ⁻²	No. of filled grains panicle ⁻¹	1000 grain weight (g.)
T ₁	148f	96g	20.50	173f	101f	20.87
T ₂	224d	125de	21.32	246d	130d	21.39
T ₃	194e	109f	20.89	219e	117e	20.98
T ₄	246c	131d	21.40	268c	142c	21.49
T ₅	282b	161b	21.60	306b	165b	21.87
T ₆	201e	113f	20.95	224e	119de	21.11
T ₇	258c	144c	21.42	281c	148c	21.51
T ₈	301a	174a	21.89	330a	180a	22.00
T ₉	207de	115ef	21.20	232de	123de	21.33
T ₁₀	261c	148c	21.47	284c	151c	21.55
T ₁₁	309a	176a	22.00	335a	185a	22.09
T ₁₂	211de	119ef	21.25	237de	126de	21.36
SEd	9	5	1.06	10	6	1.07
CD (P=0.05)	18	10	NS	20	11	NS

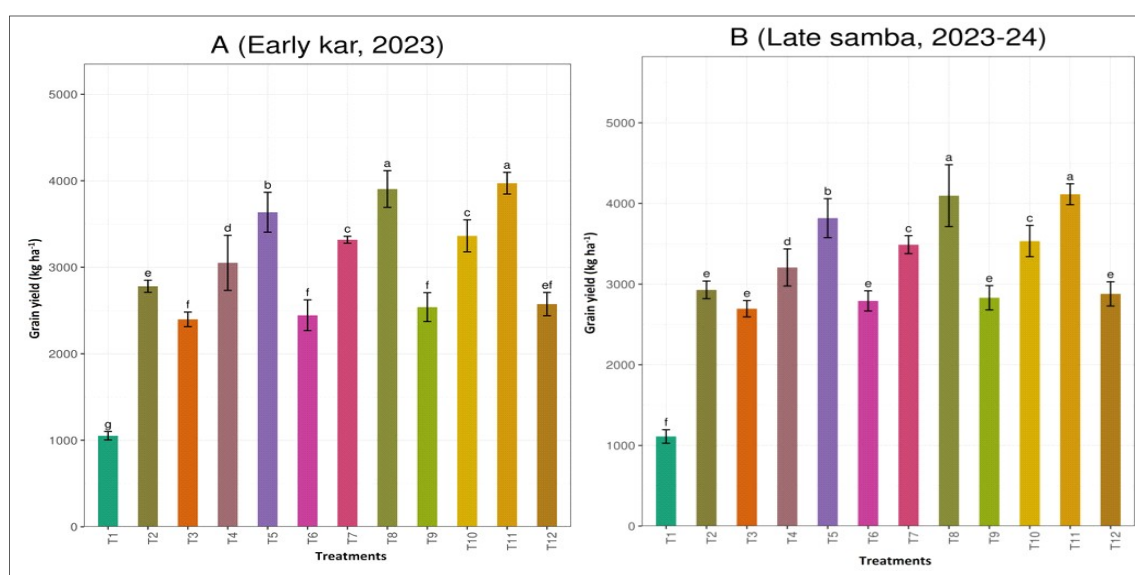


Fig 3: Effect of INM on (A.) Grain yield (kg ha⁻¹) during *Early kar* (2023) (B.) Grain yield (kg ha⁻¹) during *Late samba* (2023-24) of rice.

to translocate assimilates from source to sink (Hussian Atlaf *et al.*, 2024). The application of organic and inorganic sources of nutrients simultaneously preserves plant nutrient storage in the soil and not only increased growth but also increased translocation of source to sink, Foliar sprayed Zn and Fe to break the yield barriers, which resulted in higher yield. This is in consonance with the findings of Namrata Diwedi *et al.* (2024). Treatment without application of nutrients control (T₀) registered significantly lower yield parameters and grain yield.

CONCLUSION

From this field experiment, it could be concluded that 50% RDN through inorganic fertilizer + 50% RDN through vermicompost + foliar spray of 0.5% ZnSO₄ + 1% FeSO₄ at Tillering, PI and Flowering stage was found to be better in increasing of plant growth, root characters, physiological parameters and yield in improved traditional black kavuni rice. The decline in the level of micronutrients in soil could be mitigated by the foliar sprayed Fe and Zn nutrients to rice, which could contribute for the increased yield of rice.

Conflict of interest

The authors declare that there is no conflict of interest.

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